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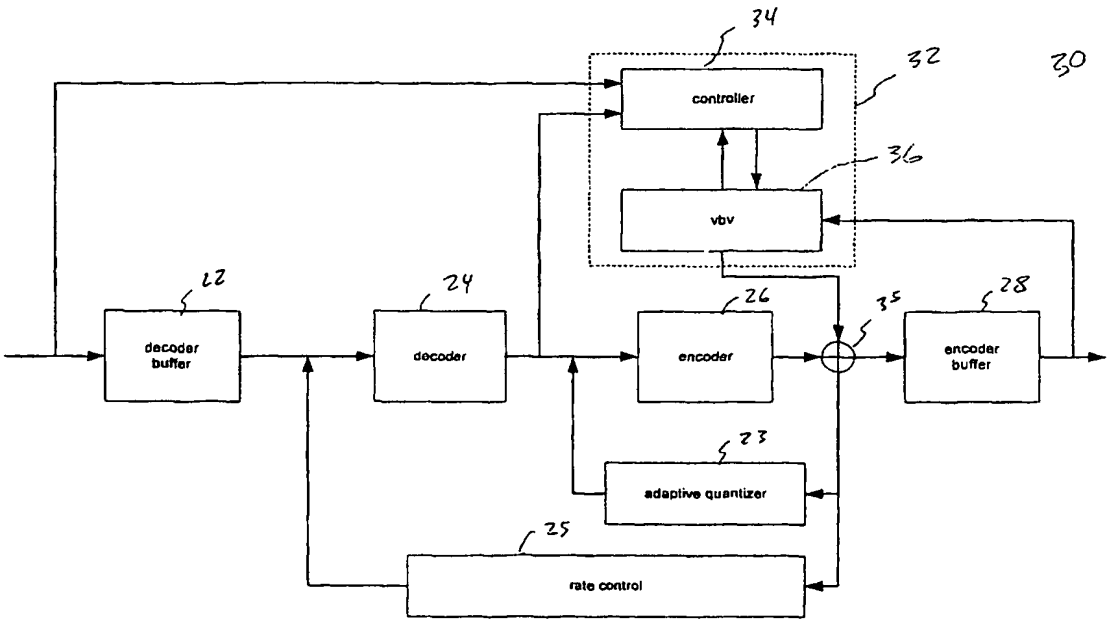

(57) Abstract

A video buffer rate-management system and method for a transcoder buffer is disclosed. The rate-management system includes logic circuitry for determining a bit budget for a current picture at an input to the decoder, measuring a buffer fullness of an encoder buffer when the encoder buffer receives a previous picture, and allocating a number of bits to the current picture based on the buffer fullness, such that the allocated bits of the current picture is within the bit budget.

NSDOCID: <WO 0046997A1 I >

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JSDOCID <WO 0046997A1 I >

VIDEO RATE-BUFFER MANAGEMENT SCHEME FOR MPEG TRANSCODER

CROSS-REFERENCES TO RELATED APPLICATIONS

This application claims priority from Provisional U.S. Patent Application No. 60/118,965, filed February 4, 1999, the disclosure of which is incorporated herein in its entirety by reference for all purposes.

BACKGROUND OF THE INVENTION

The present invention relates generally to the encoding and decoding of multimedia data, and more particularly the invention relates to rate-buffer management in a transcoder of encoded, precompressed video data.

A transcoder is a device that receives a bitstream that is pre-compressed and pre-encoded according to one of many digital transmission techniques, and outputs a compressed bitstream of a different transmission bit-rate. A simplified block diagram of a transcoder system 10 including a transcoder 12 is shown in Fig. 1. The transcoder 12 accepts a precompressed, encoded signal of video frames on an input from a transmission channel. The transmission channel may be a satellite transmission network, or cable transmission medium, for example. The input signal is decoded by a decoder 12 and re-encoded by an encoder 14, whereupon the re-encoded signal is output at a different, usually constant, bit-rate. Using well-known techniques of adjusting a quantization level of the re-encoded signal, careful management of encoder parameters can provide a high quality signal at a desired bit-rate that is tailored for a specific output transmission channel or application.

An MPEG-2 video transcoder is a specific example of a transcoder that may employ techniques of the present invention. MPEG-2 is a conventionally accepted standard for digitally coding moving pictures, such as a video signal, for compressed transmission. The MPEG-2 video transcoder converts a pre-encoded and compressed video bitstream according to MPEG-2 video compression standards into another MPEG-2 encoded, compressed video signal for transmission at a different bit-rate.

An MPEG bitstream has six layers of syntax, at which certain coding parameters are specified. There are a sequence layer (random access unit, context), Group of Pictures (GOP) layer (random access unit, video coding), picture layer (primary

ISDOCID <WO 0046997A1 I >

coding layer), slice layer (resynchronization unit), macroblock layer (motion compensation unit), and block layer (DCT unit).

The term "signal" is applied herein to mean any picture, frame, or block. A block is an 8-row by 8-column matrix of pixels. A macroblock (MB) is four 8x8 blocks of luminance data and 2, 4 or 8 corresponding 8x8 blocks of chrominance data derived from a 16x16 section of the luminance component of the picture. A slice refers to a series of macroblocks. Blocks of source data may be encoded by frame, macroblock, or slice. The first bit-rate may be for high-capacity satellite transmission of a coded source video, and the second bit-rate may be downscaled for lower-capacity local cable transmission, ultimately to a set-top box decoder to an individual viewer. A Group of Pictures (GOP) is a set of frames which starts with an I-frame and includes a certain number of P and B frames. The number of frames in a GOP may be fixed. Data rate for a given bitstream is directly related to buffer size and the speed with which bits are placed into and emptied from the buffer.

Every transcoder employs some type of video rate-buffer management technique for preventing buffer under- and/or over-flows. In a decoder buffer under-flow situation, the decoder buffer is being emptied faster that it is being filled. Consequently, too may bits are being generated in the encoder, which will eventually overflow. To prevent decoder underflow, video rate-buffer management may provide for an increased quantization level, adjust the bit allocation, discard high frequency DCT coefficients, or repeat pictures.

In a decoder buffer over-flow situation, the decoder buffer is being filled faster than it is being emptied. In other words, too many bits are being transmitted and too few bits are being removed by the decoder such that the buffer is full. Consequently, too few bits are being generated in the encoder, which will eventually underflow. Some video rate-buffer management techniques employed to avoid this situation include decreasing the quantization level, adjusting the bit allocation, and stuffing bits.

Quantization level and bit allocation adjustments are conventionally accomplished by rate control algorithm along with an adaptive quantizer. A transcoder system 20 is illustrated in Fig. 2 with rate control 25 and adaptive quantization 23 mechanisms. Generally, an encoded, compressed signal is first stored in a decoder buffer 22, and then decoded at a decoder 24 in blocks or group of blocks. Rate control 25 is applied to control a data rate of bits being removed from the decoder buffer 22, based on a number and rate of bits being added to an encoder buffer 28. Adaptive quantization

ISDOCID <WO 0046997A1 I >

adjusts a quantization level of a $_{bitstream}$ as it is re-encoded by the encoder 26. Rate control and adaptive quantization are generally accomplished in three steps:

1. Bit Allocation

Most encoders have an optimized, and often complicated, bit-allocation algorithm to assign the number of bits for each type of pictures (I-, P-, and B-pictures). Conventional bit-allocation techniques take into account the prior knowledge of video characters (e.g. scene changes, fade, etc.) and coding types (e.g. picture types) for a group of pictures (GOP) by estimating a complexity and allocating target bits for a given GOP.

Complexity Estimation: each picture type of I, P, and B pictures is assigned a relative weight X according to a global complexity measure of a Complexity Estimation technique. These weights (Xi, Xp, Xb) are reflected in a typical coded frame size of I, P, and B pictures. I pictures are assigned the largest weight since they have the greatest stability factor in an image sequence. B pictures are assigned the smallest weight since B data does not propagate into other frames through the prediction process.

Picture Target Setting: allocates target bits for a frame based on the frame type (I, P, and B) and the remaining number of frames of that same type in the GOP.

2. Rate Control

Rate control attempts to adjust bit allocation if there is significant difference between the target bits (anticipated bits) and actual encoded bits for a block of data.

3. Adaptive Quantization

Adaptive quantization is applied in the encoder along with rate-control to ensure the required video quality and to satisfy the buffer regulation. Adaptive quantization usually recomputes the macroblock quantization factor according to a comparison of the activity of a block against the normalized activity of the frame. The effect of this is to roughly assign a constant number of bits per macroblock, which results in a more perceptually uniform picture quality.

As video distribution networks grow larger and more complex, transcoders using rate-control and adaptive quantization are required to be lower-cost, simple, and yet retain a good video quality. A video rate-buffer management scheme that includes a simplified rate-control and adaptive quantization algorithm is therefore highly desirable.

ISDOCID: <WO 0046997A1 I >

SUMMARY OF THE INVENTION

The present invention provides a simplified rate control algorithm for a conventional video transcoder without requiring the GOP information. This may be accomplished by maintaining picture types, re-using motion vectors, and minimizing changes to the macroblock mode, and achieve the required video quality.

According to one embodiment, the present invention provides a method of managing a video transmission bit-rate in a transcoder. The method includes the steps of measuring a fullness of an input buffer of the transcoder, providing a bit budget for one of plurality of frames in an input bitstream, the bit budget being based on a quantization parameter of said video frames, measuring an actual bit-rate of said input video stream, and comparing said actual bit-rate with said buffer fullness to predict an input buffer underflow or overflow. In response to an input buffer underflow, the bit budget is incremented for a next one of said plurality of video frames. In response to an input buffer overflow, the bit budget is decremented for next one of said plurality of video frames.

According to another embodiment, the present invention provides a method of controlling a bit-rate of a plurality of pictures in a video transcoder, where the transcoder includes a decoder and an encoder. The method includes the steps of determining a bit budget for a current picture at an input to the decoder, measuring a buffer fullness of an encoder buffer when the encoder buffer receives a previous picture, and allocating a number of bits to the current picture based on the buffer fullness, such that the allocated bits of the current picture is within the bit budget.

Other features and advantages of the present invention will be understood upon reading and understanding the detailed description of the preferred embodiments below, in conjunction with reference to the drawings, in which like numerals represent like elements.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 schematically illustrates a conventional video transcoder system.

Fig. 2 schematically illustrates a conventional video transcoder system with adaptive quantizer and rate-control mechanisms.

Fig. 3 schematically illustrates a video transcoder system including a video rate-management controller according to an embodiment of the present invention.

SDOCID <WO__0046997A1 I >

Fig. 4 illustrates a processor block of the video rate-management scheme according to an embodiment of the present invention.

Fig. 5 illustrates a processor block of the video rat-management scheme according to an alternative embodiment of the present invention.

DESCRIPTION OF THE SPECIFIC EMBODIMENTS

The present invention provides a rate control process for efficient video rate-buffer management. According to a preferred exemplary embodiment of the invention, the rate control process is implemented in a video transcoder to control a transcoder output bitstream which complies with the requirements of the Video Buffering Verifier that are specified in the MPEG-2 video standard (ISO/IEC 13818-2).

Fig. 3 illustrates a video transcoder 30 with a video rate-management system 32 according to an embodiment of the present invention. The video rate-management system operates according to a rate management process. The rate management system 32 includes a controller 34 operatively coupled to the transcoder, and providing instructions to a Video Buffering Verifier (VBV) 36.

A Video Buffering Verifier (VBV) is a virtual decoder that is conceptually connected to the output of the encoder. Its purpose is to provide a constraint on the variability of the data rate that an encoder or editing process may produce (ISO13818-2 Annex C). The VBV contemplates a buffer in the receiver at the receiving end of the output transmission channel (not shown), and a prediction mechanism in the encoder. The prediction mechanism may a processor and control circuit that predicts a fullness of the buffer, i.e. buffer fullness, due to the constant fill from the constant bit-rate (CBR) stream and the variable empty from the variable bit-rate (VBR) due to the decoder bit demand.

In an embodiment of the present invention, the controller 34 prevents encoder VBV 36 buffer under- and/or over-flows. The encoder VBV buffer may be a shifted "mirror" of a decoder VBV buffer, however for simplification only the encoder VBV will be discussed in detail. For Constant Bit-rate (CBR) applications, by a use of rate-control, a bit-count-per-second must precisely converge to the target bit-rate with good video quality. For Variable Bit-rate (VBR) applications, the rate-control achieves the goal of maximizing the perceived quality of decoded video sequence with the maintained output-bit-rate within permitted bounds. By employing a rate-management system of the present invention with rate control, transcoder buffer under- and over-flows

ISDOCID <WO 0046997A1 I >

are avoided without adding too much complexity to the overall operation of the transcoder system.

In accordance with the invention, for a number of pictures 1-j, the VBV buffer is characterized by the following parameters:

vbv_buffer_fullness(j): the encoder VBV buffer bit-level right before encoding of the j-th picture.

coded_pict_size(j): the bit-count of the j-th coded picture.

bits_increment(j+1): the number of bits transmitted between the j-th and (j+1)-th coded pictures.

vbv_buffer_size: the (decoder) VBV buffer size coded in the sequence header and sequence extension if present.

These parameters satisfy the recursive equation:

$$\text{vbv_buffer_fullness}(j+1) = \text{vbv_buffer_fullness}(j) + \text{coded_pict_size}(j) - \text{bits_increment}(j+1). \quad (1a)$$

Assume the encoding time of j-th picture is $t_{e,j}$ and decoding time of j-th picture is $t_{d,j}$. Then an upper bound on the VBV fullness is:

$$\text{vbv_buffer_fullness}(j) + \text{coded_pict_size}(j) < \int_{t_{e,j}}^{t_{d,j}} R(t)dt \quad (1b)$$

The VBV fullness upper bound is illustrated in Fig. 4, and

$$\int_{t_{e,j}}^{t_{d,j}} R(t)dt < \text{vbv_buffer_fullness}(j) + \text{vbv_buffer_size}, \quad (1c)$$

Where $R(t)$ is the bit-rate function. The left-side of Eq. (1c) is set to a maximum value as $T_{max}=(t_{d,j} - t_{e,j})\, R_{max}$.

(1d)

Where $t_{d,j} - t_{e,j}$ is the delay of the channel and R_{max} is the maximum channel bit-rate between $t_{d,j} - t_{e,j}$.

Therefore, a VBV fullness lower bound is:

ISDOCID: <WO 0046997A1 I >

$$vbv_buffer_fullness(j) > -vbv_buffer_size + T_{max}. \quad (1e)$$

The VBV fullness lower bound is illustrated in Fig. 5

A video rate-buffer management process according to the invention can be accomplished with rate-control and adaptive quantization for efficient buffer-control.

The rate-buffer management system and method according to an embodiment of the present invention checks a bitstream to verify that the amount of rate-buffer memory required in the decoder is bounded by the vbv_buffer_size. The rate-control process will be guided by the rate-buffer management protocol to ensure the bitstream satisfying the buffer regulation with good video quality.

In one step of the rate-buffer management and rate-control process, a bit-budget is determined for each picture. In one embodiment of the invention, for the MPEG-2 transcoder for example, a bit-allocation process is followed for determining the bit-budget for each picture. According to the process, and for convenience of discussion, the following terms define the encoder VBV buffer-related variables:

target_bit_rate: the VBR or CBR bit rate from a storage media to the decoder;

target_pict_size: the targeted bit-count of the current picture, often call the bit-budget for the picture.

input_bit_rate: the bit rate of the input bitstream,

input_pict_size: the bit-count of the current input (coded) picture (without picture header bits);

coded_pict_size: the actual bit-count of the current coded picture (without picture header bits).

frame_rate: the frame rate of the video sequence given in the sequence header.

max_vbv_buffer_fullness(j): assigned for the j-th picture or the j-th GOP.

According to the invention, the bit-budget for the j-th picture is allocated by a down-scaling transformation as follows:

$$target_pict_size(j) = input_pict_size(j) * (target_bit_rate / input_bit_rate).$$

In an alternative embodiment, bit-allocation for the j-th picture accumulates the bit-budgets of all macroblocks (MBs):

SDOCID <WO__0046997A1 I >

$$target_pict_size(j) = \sum_{i=0}^{munber_of_MBs-1} round(input_mb_size(i) * target_bit_rate / input_bit_rate + 0.5)$$

where the *round*(*) function performs a rounding-toward zero and *input_mb_size(i)* denotes the bit-count of the i-th input MB. It should be understood that *input_mb_size(I)*target_bit_rate/input_bit_rate* is the target MB size. The bit-budget *target_pict_size(j)* for the j-th picture is checked against the *vbv_buffer_fullness(j)* to prevent the VBV buffer under- and over-flows. The condition on the VBV buffer under-flow provides an upper limit on the bit-budget. The reason is that, at the time of decoding, the current picture should be small enough so that it is contained entirely inside the decoder buffer.

It is known for transcoder that *target_pict_size(j)* needs to satisfy *target_pict_size(j) < input_pict_size(j).*

If the current picture size is too small, then Eq. (1a) might exceed the *max_vbv_buffer_fullness(j+1)* and then cause decoder buffer overflow. Thus a lower limit is placed on the current picture size. This may be achieved, for example, by limiting the bit budget, and if the actual bits used is still smaller than the minimum picture size, then the end of the picture may be stuffed with zero's. The lower limit is derived from Eqs.(1a) and (1e) as follows.

target_pict_size(j) > vbv_buffer_size + T_{max} - vbv_buffer_fullness(j-1) + T_{min} .

where $T_{min}=(t_{e,j} - t_{e,j-1})\ R_{min}$ and R_{min} is the maximum channel bit-rate between $t_{e,j} - t_{e,j-1}$. Note that $R_{min} = R_{max}$ for the CBR channel.

The inequality condition of (1e) is verified for each slice or frame to prevent the encoder buffer under-flow.

Down-scaling bit-allocation takes advantage of information provided by the input bitstream for CBR applications. For VBR applications, the down-scaling process requires an instantaneous bit-rate for each picture or every few pictures. This bit-rate, associated with *max_vbv_buffer_fullness*, can be provided from StatMux.

It is shown in the next section that the target picture size or the target MB size will effect the virtual buffer fullness and, as a consequence, it will generate the quantization scale for the corresponding MB.

In general, the quantization scale (denoted by *mquant*) for the transcoded bitstream can also generated through a scaling process. Some commonly-used bit-allocation models are:

NSDOCID: <WO 0046997A1 I >

(1) $T = \frac{k_0}{Q}$ in MPEG-2 Test Model 5(TM5) [3].

(2) $T = \frac{k_0}{Q} + \frac{k_1}{Q^2}$ in MPEG-4 verification model [4].

Where T is the bit-budget for a picture or a slice or a MB, and k_0, k_1 are constants that are generated by a pre-estimation[4], and Q denotes the quantization scale corresponding to a picture or a slice or a MB, respectively. Since $T_{target} / T_{input} = target_bit_rate / input_bit_rate$, the quantization scale for the transcoded MBs thus can be estimated by:

For the model $T = \frac{k_0}{Q}$, $Q_{target} = Q_{input} \cdot \frac{input_bit_rate}{target_bit_rate}$,

For the model $T = \frac{k_0}{Q} + \frac{k_1}{Q^2}$, the quantization scale Q can be computed by solving a quadratic equation : $Q_{target} = \frac{k_0 + \sqrt{k_0^2 + 4 \cdot B \cdot k_1}}{2 \cdot B}$ where

$$B = \frac{target_bit_rate}{input_bit_rate} \cdot \left(\frac{k_0}{Q_{input}} + \frac{k_1}{Q_{input}^2} \right).$$

Where Q_{input} can be the average quantization level for this picture or slice at the input, or the quantization level of the MB at the input. The same process can also be applied to other bit-allocation models.

Adjustment to the quantization scale may be accomplished according to the embodiment illustrated below. Let Q_v denote the quantization scale determined by the virtual buffers fullness and Q_{target} be the up-scaled quantization level given above.

Assume that Q_{target} is the up-scaled quantization level for a given MB. Then, the quantization scale Q_T for the MB is determined by

If($\sum_{0}^{current}$ coded_mb_size> $\sum_{0}^{current}$ target_mb_size)

$$Q_T = \max\left(Q_{target}, Q_v\right);$$

else

$$Q_T = \min\left(Q_{target}, Q_v\right).$$

SDOCID: <WO___0046997A1_I_>

In an alternative embodiment, the quantization scale may be adjusted as follows. Assume that Q_{target} is the up-scaled quantization level for a given picture or slice at the input and Q_{input} is the average quantization level for this picture or slice at the input, respectively. Then,

$$Q_{targetMB} = Q_{inputMB} + (Q_{input} - Q_{target}) .$$

The quantization level Q_T for the MB is determined by

$$\text{If}\Big(\sum_{0}^{current} \text{coded_mb_size} > \sum_{0}^{current} \text{target_mb_size}\Big)$$

$$Q_T = \max\left(Q_{targetMB}, Q_v\right),$$

else

$$Q_T = \min\left(Q_{targetMB}, Q_v\right).$$

The down-scaling process for bit-allocation is applied to the macroblock levels for their bit-budget estimation, and is described below with rate-buffer management and rate-control. According to an embodiment of the present invention, a rate management process includes five steps. In this embodiment, the down-scaling process for bit-allocation is only applied to the macroblock levels, which simplifies the bit- parser and counting process. For CBR applications, such a down-scaling process ensures that the VBV buffer never overflows for a "legal" input bitstream.

1. Initial conditions in Sequence Level

The *vbv buffer* is initially filled the *vbv_buffer_fullness* amount of bits. For CBR applications, *vbv_buffer_fullness* =vbv_delay*target_bit_rate/90000. For VBR applications, the initial *vbv_buffer_fullness* is often derived from the decoding time-stamp of the first picture, i.e. *vbv_buffer_fullness = buffer bit level right before decoding of the first picture.* For the elementary stream-only case, it is initially assumed that:

vbv_buffer_fullness = max(min((2**bit_rate*)/*frame_rate*, *max_vbv_buffer_fullness*/ 5), K1)

if the initial quantizer is non-linear and:

vbv_buffer_fullness = max(min((4**bit_rate*)/*frame_rate*, *max_vbv_buffer_fullness*/ 2), K2)

SDOCID <WO 0046997A1 i >

if the initial quantizer is linear , where K1 and K2 are constants. In one embodiment, the values for the constants may be K1=100000 and K2=200000. In an alternative embodiment of the invention, in a similar manner to the MPEG-2 test model 5 (TM5) [3], three virtual buffers are used to measure the buffer fullness.

2. Initial Conditions in Picture Level

The additional parameters required in the picture level are the quantization scale type : *q_scale_type* and the average quantization level *avg_Q_prev_pict* of the previous picture.

Two variables need to be set for the rate-control in the picture level: (1) the initial virtual buffer fullness for the picture; (2) the bit budget for this picture. Also, the bits from picture header (and sequence header and GOP header for the beginning of the sequence or GOP) , *header_bits,* are extracted.

The virtual buffer fullness *d* is set to be the virtual buffer fullness of the current picture type, i.e.

case I_TYPE : $d = d0i$;

case P_TYPE : $d = d0p$;

case B_TYPE : $d = d0b$.

(2) The bit budget for this picture, denoted by *target_pict_size*, is allocated by a very simple transformation as follows:

target_pict_size = input_pict_size(target_bit_rate/input_bit_rate)*

For CBR applications, *target_bit_rate/input_bit_rate* is pre-computed after parsing the sequence header.

3. Update Variables in Picture Level

Two variables are updated in the picture level: the virtual buffer fullness *d.* and the quantization type *q_scale_type* for this picture.

(1) d + = *coded_pict_size* – *target_pict_size* , and

case I_TYPE : $d0i=d$;

case P_TYPE : $d0p=d$;

case B_TYPE : $d0b=d$

(2) The *q_scale_type* for this picture is determined by the following rules :

If this picture is the first picture or an I-picture, keep the *q_scale_type* to be the same as the corresponding input picture;

SDOCID: <WO__0046997A1_I >

Otherwise, *q_scale_type* is set as follows :

If (*avg_Q_prev_pict<T1* || *avg_Q_prev_pict>T2*) *q_scale_type = 1 ;*

If (*avg_Q_prev_pict > T3 && avg_Q_prev_pict < T4) q_scale_type = 0;*

Where avg_Q_prev_pict is the average mquant of the previous frame and *T1<T3<T4<T2*. The typical values for *T1, T2, T3*, and *T4* are:

T1=15, T2=25, T3=18 and *T4 =22.*

If *q_scale_type* is not set, the input *q_scale_type* is used.

At the end of a picture, the video buffer verifier fullness *vbv_buffer_fullness* is updated. The minimum picture size *min_pict_size* is compared with the actual coded picture size *coded_pict_size* for the frame just coded. If a deficit exists, ones are appended to the end of that frame.

4. Initial Variables in Macroblock Level

An initial quantization step-size (mquant) needs to be computed at the beginning of each picture. Such a quantization step-size is generated by an up-scaling conversion of the quantization step-size (input_mquant) of the corresponding input macroblock :

mquant = input_mquant*(input_bit_rate/target_bit_rate);

5. Updated Variables in Macroblock Level

The macroblock (MB) quantization step-size, mquant, is updated by a use of a virtual buffer discrepancy. The virtual buffer discrepancy is calculated by the following formula :

Virtual buffer discrepancy = d + the cumulated bits up to the current MB of a picture - the cumulated MB-bit-budget up to the current MB of a picture.

The MB-bit-budget for each MB may also be computed by a down-scaling conversion:

mb_bit_budget = input_mb_bitcount*(target_bit_rate/input_bit_rate).

Although the invention has been described with reference to specific exemplary embodiments, it will be appreciated that it is intended to cover all modifications and equivalents within the scope of the appended claims.

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WHAT IS CLAIMED IS:

1. A method of managing a video transmission bit-rate in a transcoder, comprising the steps of:

measuring a fullness of an input buffer of the transcoder;

providing a bit budget for one of plurality of frames in an input bitstream, the bit budget being based on a quantization parameter of said video frames;

measuring an actual bit-rate of said input video stream;

comparing said actual bit-rate with said buffer fullness to predict an input buffer underflow or overflow; and

in response to an input buffer underflow, incrementing said bit budget for a next one of said plurality of video frames, and in response to an input buffer overflow, decrementing said bit budget for next one of said plurality of video frames.

2. A method of controlling a bit-rate of a plurality of pictures in a video transcoder, where the transcoder includes a decoder and an encoder, the method comprising the steps of:

determining a bit budget for a current picture at an input to the decoder;

measuring a buffer fullness of an encoder buffer when the encoder buffer receives a previous picture; and

allocating a number of bits to the current picture based on the buffer fullness, such that the allocated bits of the current picture is within the bit budget.

3. The method according to claim 2, wherein the step of determining a bit budget further comprises the steps of:

determining a size of available encoder buffer capacity after the encoder buffer receives a previous picture; and

measuring a coded picture size of the current picture at the input to the decoder.

4. The method according to claim 2, wherein the step of measuring a buffer fullness further comprises the step of determining the encoder buffer capacity.

5. The method according to claim 2, wherein the step of allocating a number of bits to the current picture further comprises the step of adjusting a quantization of a decoded picture.

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6. The method according to claim 2, wherein the step of allocating a number of bits to the current picture further comprises the steps of:

setting a target bit size for the current picture;

measuring an actual bit size for the current picture; and

adjusting a quantization level for the current picture based on a differential between the target bit size and the actual bit size for the current picture,

wherein the target bit size is calculated to be within a range of available encoder buffer bit space.

7. A system for controlling a bit-rate of a plurality of pictures in a video transcoder, where the transcoder includes a decoder and an encoder, comprising:

means for determining a bit budget for a current picture at an input to the decoder;

means for measuring a buffer fullness of an encoder buffer when the encoder buffer receives a previous picture; and

means for allocating a number of bits to the current picture based on the buffer fullness, such that the allocated bits of the current picture is within the bit budget.

8. The system according to claim 7, further comprising:

a video buffering verifier having configured to monitor the encoder buffer and measure the buffer fullness; and

a controller, coupled with the video buffering verifier, and configured to receive bit-rate information from a transmission channel input to the decoder, wherein the bit-rate information is compared with the buffer fullness to allocate the number of bits to the current picture.

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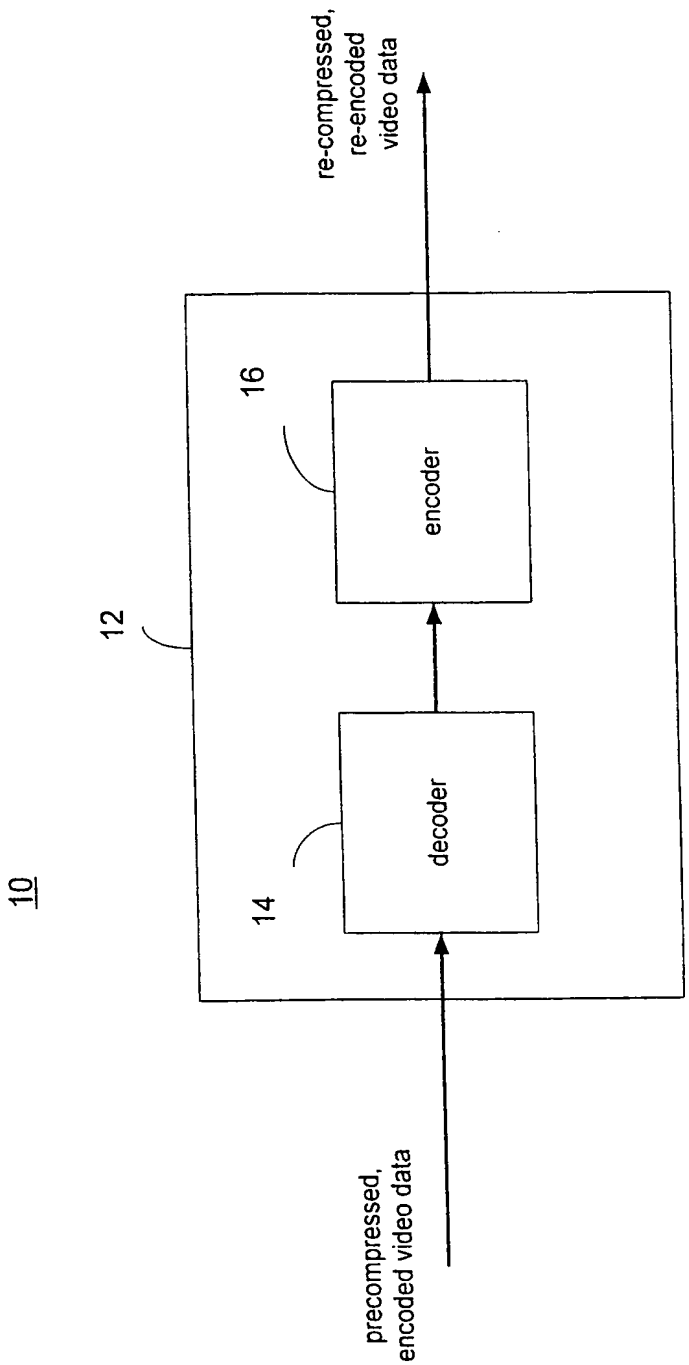

Fig. 1 (prior art)

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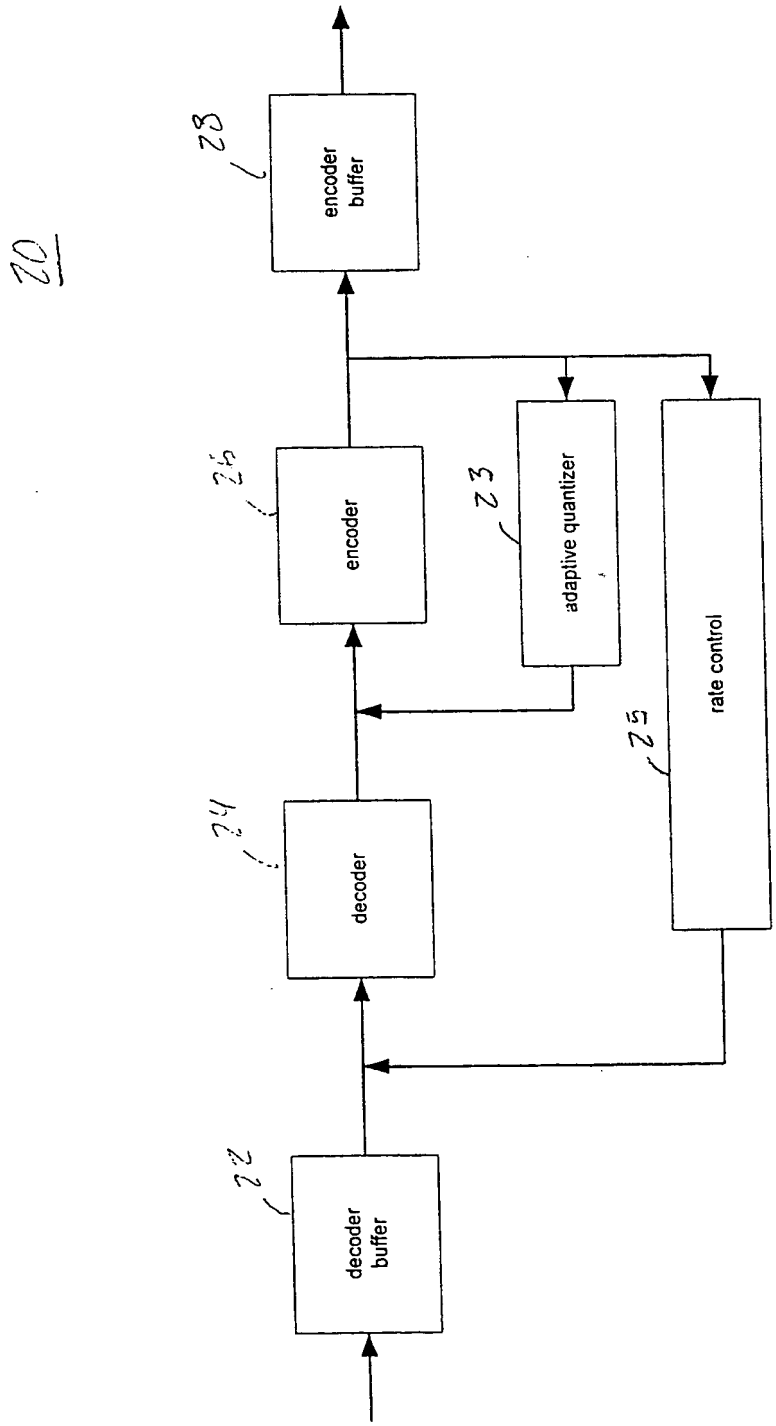

Fig. 2 (prior art)

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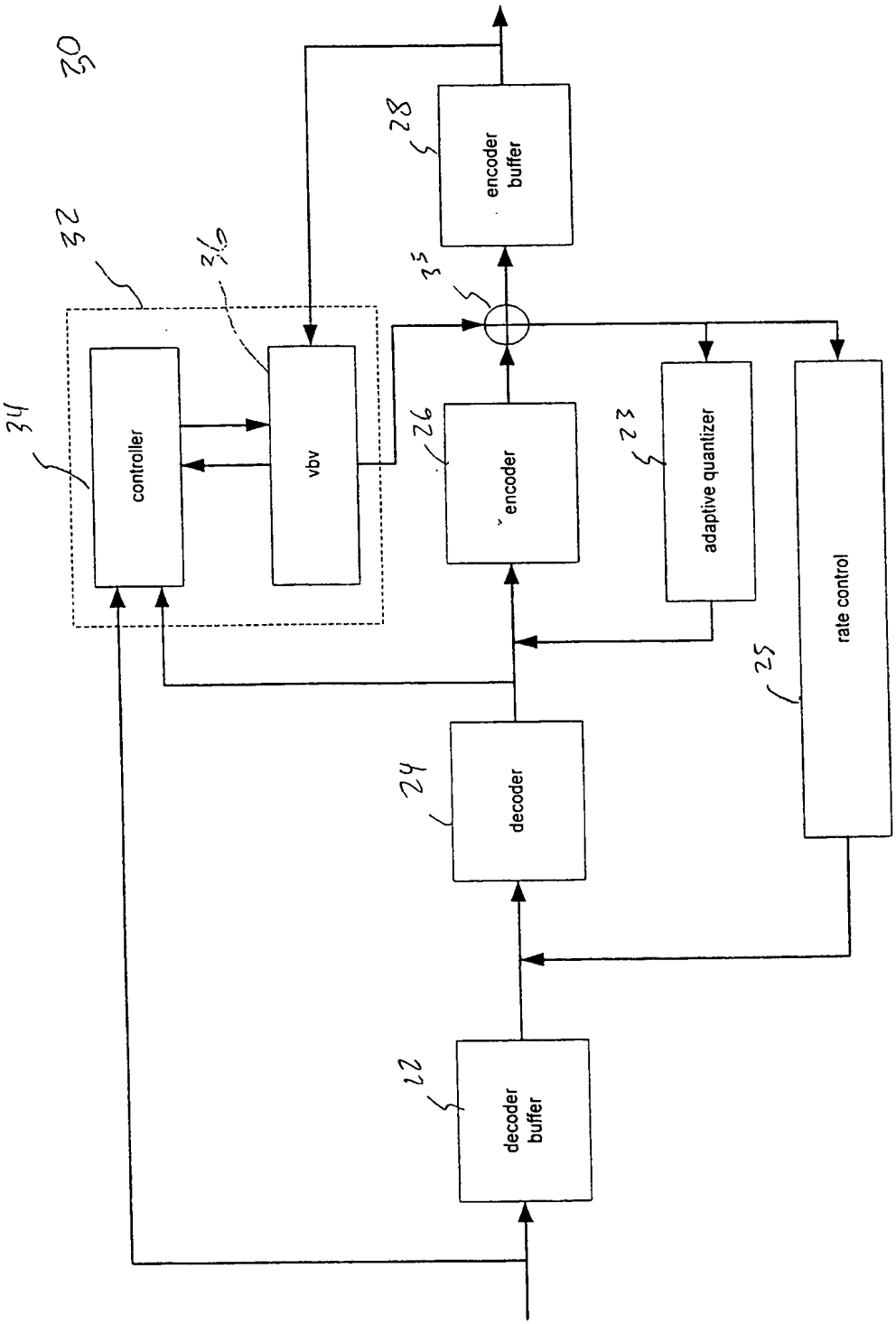

Fig. 3

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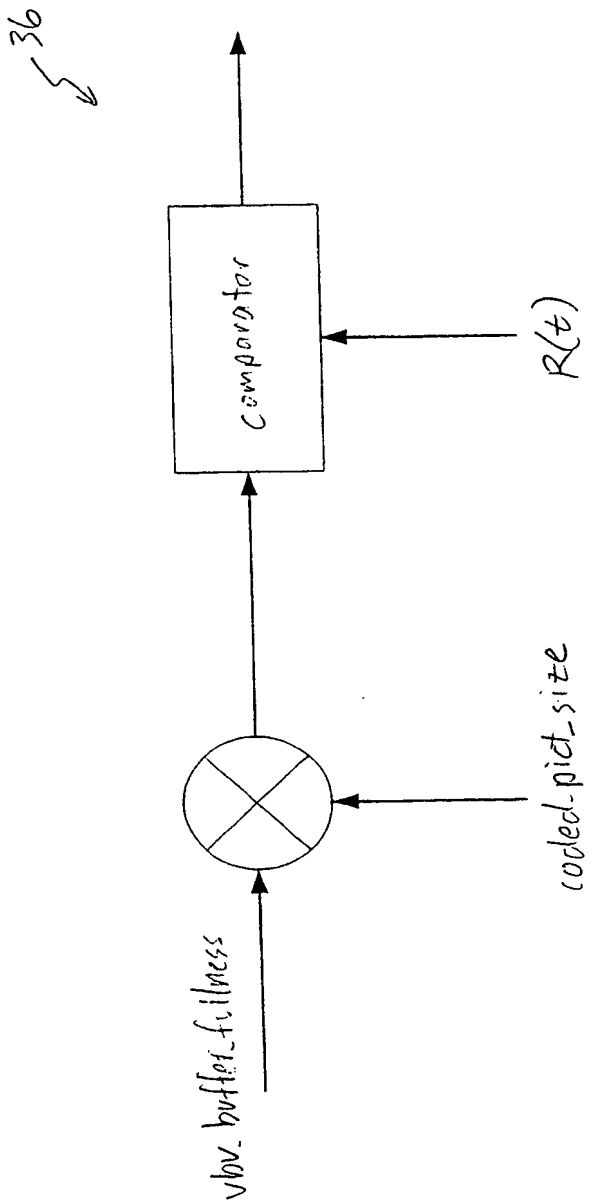

Fig 4.

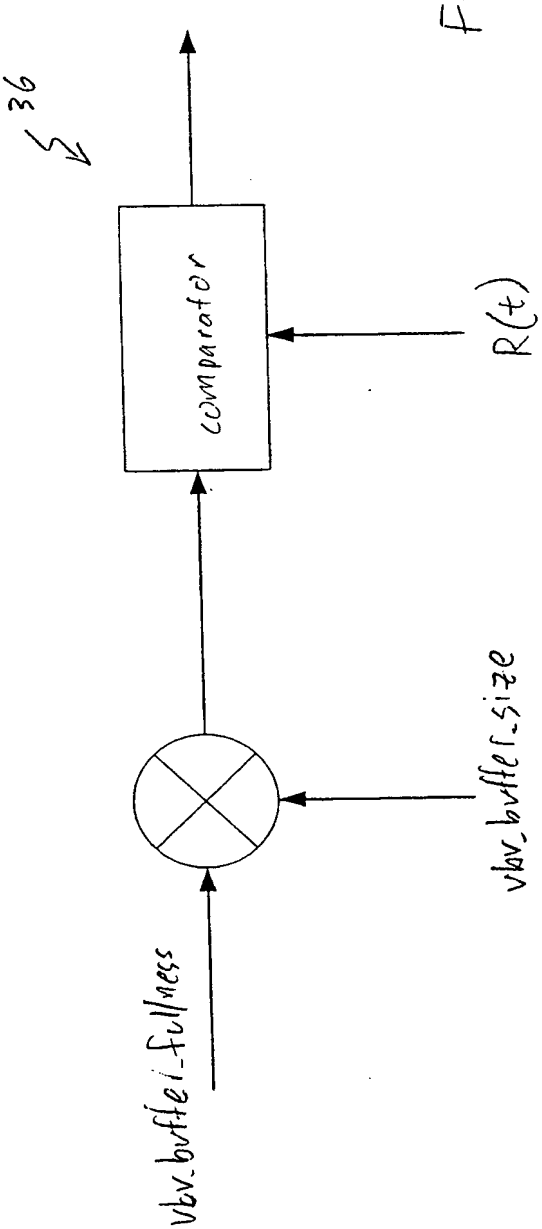

Fig 5

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INTERNATIONAL SEARCH REPORT

Int. ional Application No
PCT/US 00/02967

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04N7/26 H04N7/50

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 711 077 A (AT & T CORP) 8 May 1996 (1996-05-08)	2-5,7
A	page 4, column 5, line 43 -column 6, line 27 page 7, column 12, line 16 -page 8, column 14, line 32	7,8
A	US 5 805 224 A (VAN OTTERLOO PETRUS J ET AL) 8 September 1998 (1998-09-08) page 5, line 35 -page 6, line 21	2-7

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 June 2000	07/07/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl. Fax: (+31-70) 340-3016	Marie-Julie, J-M

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INTERNATIONAL SEARCH REPORT

Int. ional Application No
PCT/US 00/02967

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	SUN H ET AL: "ARCHITECTURES FOR MPEG COMPRESSED BITSTREAM SCALING" IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY,US,IEEE INC. NEW YORK, vol. 6, no. 2, 1 April 1996 (1996-04-01), pages 191-199, XP000583538 ISSN: 1051-8215 paragraphs '000A!,'000B!	1

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Int tional Application No
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		CA 2159846 A	02-05-1996
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		JP 9512410 T	09-12-1997

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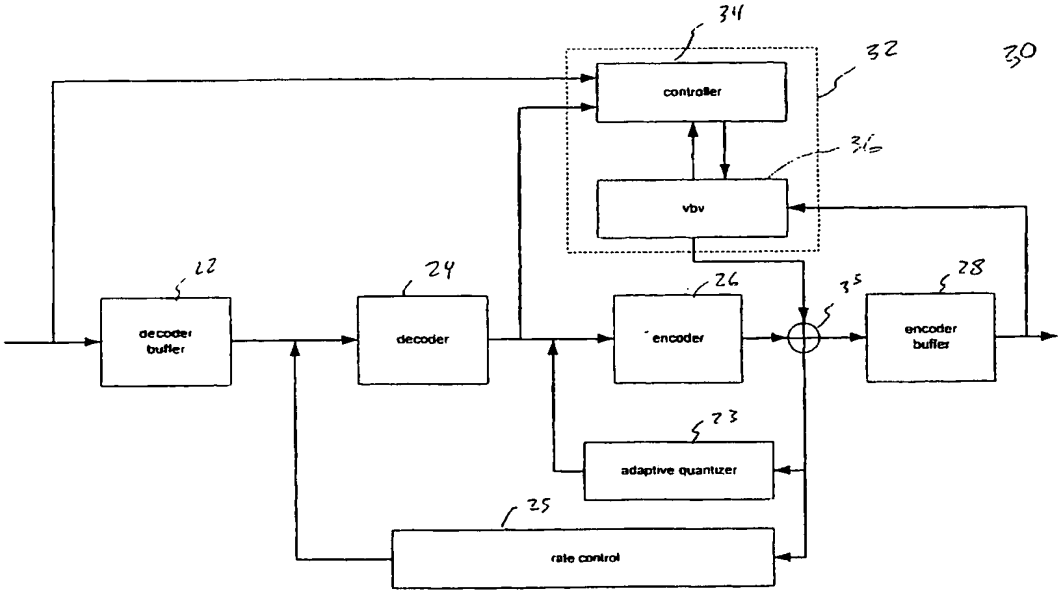
(54) Title: VIDEO RATE-BUFFER MANAGEMENT SCHEME FOR MPEG TRANSCODER



(57) Abstract: A video buffer rate-management system and method for a transcoder buffer is disclosed. The rate-management system includes logic circuitry for determining a bit budget for a current picture at an input to the decoder, measuring a buffer fullness of an encoder buffer when the encoder buffer receives a previous picture, and allocating a number of bits to the current picture based on the buffer fullness, such that the allocated bits of the current picture is within the bit budget.

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18 October 2001

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

VIDEO RATE-BUFFER MANAGEMENT SCHEME FOR MPEG TRANSCODER

CROSS-REFERENCES TO RELATED APPLICATIONS

This application claims priority from Provisional U.S. Patent Application No. 60/118,965, filed February 4, 1999, the disclosure of which is incorporated herein in its entirety by reference for all purposes.

BACKGROUND OF THE INVENTION

The present invention relates generally to the encoding and decoding of multimedia data, and more particularly the invention relates to rate-buffer management in a transcoder of encoded, precompressed video data.

A transcoder is a device that receives a bitstream that is pre-compressed and pre-encoded according to one of many digital transmission techniques, and outputs a compressed bitstream of a different transmission bit-rate. A simplified block diagram of a transcoder system 10 including a transcoder 12 is shown in Fig. 1. The transcoder 12 accepts a precompressed, encoded signal of video frames on an input from a transmission channel. The transmission channel may be a satellite transmission network, or cable transmission medium, for example. The input signal is decoded by a decoder 12 and re-encoded by an encoder 14, whereupon the re-encoded signal is output at a different, usually constant, bit-rate. Using well-known techniques of adjusting a quantization level of the re-encoded signal, careful management of encoder parameters can provide a high quality signal at a desired bit-rate that is tailored for a specific output transmission channel or application.

An MPEG-2 video transcoder is a specific example of a transcoder that may employ techniques of the present invention. MPEG-2 is a conventionally accepted standard for digitally coding moving pictures, such as a video signal, for compressed transmission. The MPEG-2 video transcoder converts a pre-encoded and compressed video bitstream according to MPEG-2 video compression standards into another MPEG-2 encoded, compressed video signal for transmission at a different bit-rate.

An MPEG bitstream has six layers of syntax, at which certain coding parameters are specified. There are a sequence layer (random access unit, context), Group of Pictures (GOP) layer (random access unit, video coding), picture layer (primary

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coding layer), slice layer (resynchronization unit), macroblock layer (motion compensation unit), and block layer (DCT unit).

The term "signal" is applied herein to mean any picture, frame, or block. A block is an 8-row by 8-column matrix of pixels. A macroblock (MB) is four 8x8 blocks of luminance data and 2, 4 or 8 corresponding 8x8 blocks of chrominance data derived from a 16x16 section of the luminance component of the picture. A slice refers to a series of macroblocks. Blocks of source data may be encoded by frame, macroblock, or slice. The first bit-rate may be for high-capacity satellite transmission of a coded source video, and the second bit-rate may be downscaled for lower-capacity local cable transmission, ultimately to a set-top box decoder to an individual viewer. A Group of Pictures (GOP) is a set of frames which starts with an I-frame and includes a certain number of P and B frames. The number of frames in a GOP may be fixed. Data rate for a given bitstream is directly related to buffer size and the speed with which bits are placed into and emptied from the buffer.

Every transcoder employs some type of video rate-buffer management technique for preventing buffer under- and/or over-flows. In a decoder buffer under-flow situation, the decoder buffer is being emptied faster that it is being filled. Consequently, too may bits are being generated in the encoder, which will eventually overflow. To prevent decoder underflow, video rate-buffer management may provide for an increased quantization level, adjust the bit allocation, discard high frequency DCT coefficients, or repeat pictures.

In a decoder buffer over-flow situation, the decoder buffer is being filled faster than it is being emptied. In other words, too many bits are being transmitted and too few bits are being removed by the decoder such that the buffer is full. Consequently, too few bits are being generated in the encoder, which will eventually underflow. Some video rate-buffer management techniques employed to avoid this situation include decreasing the quantization level, adjusting the bit allocation, and stuffing bits.

Quantization level and bit allocation adjustments are conventionally accomplished by rate control algorithm along with an adaptive quantizer. A transcoder system 20 is illustrated in Fig. 2 with rate control 25 and adaptive quantization 23 mechanisms. Generally, an encoded, compressed signal is first stored in a decoder buffer 22, and then decoded at a decoder 24 in blocks or group of blocks. Rate control 25 is applied to control a data rate of bits being removed from the decoder buffer 22, based on a number and rate of bits being added to an encoder buffer 28. Adaptive quantization

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adjusts a quantization level of a $_{bitstream}$ as it is re-encoded by the encoder 26. Rate control and adaptive quantization are generally accomplished in three steps:

1. Bit Allocation

Most encoders have an optimized, and often complicated, bit-allocation algorithm to assign the number of bits for each type of pictures (I-, P-, and B-pictures). Conventional bit-allocation techniques take into account the prior knowledge of video characters (e.g. scene changes, fade, etc.) and coding types (e.g. picture types) for a group of pictures (GOP) by estimating a complexity and allocating target bits for a given GOP.

Complexity Estimation: each picture type of I, P, and B pictures is assigned a relative weight X according to a global complexity measure of a Complexity Estimation technique. These weights (Xi, Xp, Xb) are reflected in a typical coded frame size of I, P, and B pictures. I pictures are assigned the largest weight since they have the greatest stability factor in an image sequence. B pictures are assigned the smallest weight since B data does not propagate into other frames through the prediction process.

Picture Target Setting: allocates target bits for a frame based on the frame type (I, P, and B) and the remaining number of frames of that same type in the GOP.

2. Rate Control

Rate control attempts to adjust bit allocation if there is significant difference between the target bits (anticipated bits) and actual encoded bits for a block of data.

3. Adaptive Quantization

Adaptive quantization is applied in the encoder along with rate-control to ensure the required video quality and to satisfy the buffer regulation. Adaptive quantization usually recomputes the macroblock quantization factor according to a comparison of the activity of a block against the normalized activity of the frame. The effect of this is to roughly assign a constant number of bits per macroblock, which results in a more perceptually uniform picture quality.

As video distribution networks grow larger and more complex, transcoders using rate-control and adaptive quantization are required to be lower-cost, simple, and yet retain a good video quality. A video rate-buffer management scheme that includes a simplified rate-control and adaptive quantization algorithm is therefore highly desirable.

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SUMMARY OF THE INVENTION

The present invention provides a simplified rate control algorithm for a conventional video transcoder without requiring the GOP information. This may be accomplished by maintaining picture types, re-using motion vectors, and minimizing changes to the macroblock mode, and achieve the required video quality.

According to one embodiment, the present invention provides a method of managing a video transmission bit-rate in a transcoder. The method includes the steps of measuring a fullness of an input buffer of the transcoder, providing a bit budget for one of plurality of frames in an input bitstream, the bit budget being based on a quantization parameter of said video frames, measuring an actual bit-rate of said input video stream, and comparing said actual bit-rate with said buffer fullness to predict an input buffer underflow or overflow. In response to an input buffer underflow, the bit budget is incremented for a next one of said plurality of video frames. In response to an input buffer overflow, the bit budget is decremented for next one of said plurality of video frames.

According to another embodiment, the present invention provides a method of controlling a bit-rate of a plurality of pictures in a video transcoder, where the transcoder includes a decoder and an encoder. The method includes the steps of determining a bit budget for a current picture at an input to the decoder, measuring a buffer fullness of an encoder buffer when the encoder buffer receives a previous picture, and allocating a number of bits to the current picture based on the buffer fullness, such that the allocated bits of the current picture is within the bit budget.

Other features and advantages of the present invention will be understood upon reading and understanding the detailed description of the preferred embodiments below, in conjunction with reference to the drawings, in which like numerals represent like elements.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 schematically illustrates a conventional video transcoder system.

Fig. 2 schematically illustrates a conventional video transcoder system with adaptive quantizer and rate-control mechanisms.

Fig. 3 schematically illustrates a video transcoder system including a video rate-management controller according to an embodiment of the present invention.

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Fig. 4 illustrates a processor block of the video rate-management scheme according to an embodiment of the present invention.

Fig. 5 illustrates a processor block of the video rat-management scheme according to an alternative embodiment of the present invention.

DESCRIPTION OF THE SPECIFIC EMBODIMENTS

The present invention provides a rate control process for efficient video rate-buffer management. According to a preferred exemplary embodiment of the invention, the rate control process is implemented in a video transcoder to control a transcoder output bitstream which complies with the requirements of the Video Buffering Verifier that are specified in the MPEG-2 video standard (ISO/IEC 13818-2).

Fig. 3 illustrates a video transcoder 30 with a video rate-management system 32 according to an embodiment of the present invention. The video rate-management system operates according to a rate management process. The rate management system 32 includes a controller 34 operatively coupled to the transcoder, and providing instructions to a Video Buffering Verifier (VBV) 36.

A Video Buffering Verifier (VBV) is a virtual decoder that is conceptually connected to the output of the encoder. Its purpose is to provide a constraint on the variability of the data rate that an encoder or editing process may produce (ISO13818-2 Annex C). The VBV contemplates a buffer in the receiver at the receiving end of the output transmission channel (not shown), and a prediction mechanism in the encoder. The prediction mechanism may a processor and control circuit that predicts a fullness of the buffer, i.e. buffer fullness, due to the constant fill from the constant bit-rate (CBR) stream and the variable empty from the variable bit-rate (VBR) due to the decoder bit demand.

In an embodiment of the present invention, the controller 34 prevents encoder VBV 36 buffer under- and/or over-flows. The encoder VBV buffer may be a shifted "mirror" of a decoder VBV buffer, however for simplification only the encoder VBV will be discussed in detail. For Constant Bit-rate (CBR) applications, by a use of rate-control, a bit-count-per-second must precisely converge to the target bit-rate with good video quality. For Variable Bit-rate (VBR) applications, the rate-control achieves the goal of maximizing the perceived quality of decoded video sequence with the maintained output-bit-rate within permitted bounds. By employing a rate-management system of the present invention with rate control, transcoder buffer under- and over-flows

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are avoided without adding too much complexity to the overall operation of the transcoder system.

In accordance with the invention, for a number of pictures 1-j, the VBV buffer is characterized by the following parameters:

vbv_buffer_fullness(j): the encoder VBV buffer bit-level right before encoding of the j-th picture.

coded_pict_size(j): the bit-count of the j-th coded picture.

bits_increment(j+1): the number of bits transmitted between the j-th and (j+1)-th coded pictures.

vbv_buffer_size: the (decoder) VBV buffer size coded in the sequence header and sequence extension if present.

These parameters satisfy the recursive equation:

vbv_buffer_fullness(j+1) = vbv_buffer_fullness(j) + coded_pict_size(j) - bits_increment(j+1). (1a)

Assume the encoding time of j-th picture is $t_{e,j}$ and decoding time of j-th picture is $t_{d,j}$. Then an upper bound on the VBV fullness is:

$$\text{vbv_buffer_fullness(j)} + \text{coded_pict_size(j)} < \int_{t_{e,j}}^{t_{d,j}} R(t)dt \qquad (1b)$$

The VBV fullness upper bound is illustrated in Fig. 4, and

$$\int_{t_{e,j}}^{t_{d,j}} R(t)dt < \text{vbv_buffer_fullness(j)} + \text{vbv_buffer_size}, \qquad (1c)$$

Where $R(t)$ is the bit-rate function. The left-side of Eq. (1c) is set to a maximum value as $T_{max}=(t_{d,j} - t_{e,j})\, R_{max}$.

(1d)

Where $t_{d,j} - t_{e,j}$ is the delay of the channel and R_{max} is the maximum channel bit-rate between $t_{d,j} - t_{e,j}$.

Therefore, a VBV fullness lower bound is:

ISDOCID: <WO 0046997A1 IA>

$$vbv_buffer_fullness(j) > -vbv_buffer_size + T_{max}. \quad (1e)$$

The VBV fullness lower bound is illustrated in Fig. 5

A video rate-buffer management process according to the invention can be accomplished with rate-control and adaptive quantization for efficient buffer-control.

The rate-buffer management system and method according to an embodiment of the present invention checks a bitstream to verify that the amount of rate-buffer memory required in the decoder is bounded by the vbv_buffer_size. The rate-control process will be guided by the rate-buffer management protocol to ensure the bitstream satisfying the buffer regulation with good video quality.

In one step of the rate-buffer management and rate-control process, a bit-budget is determined for each picture. In one embodiment of the invention, for the MPEG-2 transcoder for example, a bit-allocation process is followed for determining the bit-budget for each picture. According to the process, and for convenience of discussion, the following terms define the encoder VBV buffer-related variables:

target_bit_rate: the VBR or CBR bit rate from a storage media to the decoder;

target_pict_size: the targeted bit-count of the current picture, often call the bit-budget for the picture.

input_bit_rate: the bit rate of the input bitstream,

input_pict_size: the bit-count of the current input (coded) picture (without picture header bits);

coded_pict_size: the actual bit-count of the current coded picture (without picture header bits).

frame_rate: the frame rate of the video sequence given in the sequence header.

max_vbv_buffer_fullness(j): assigned for the j-th picture or the j-th GOP.

According to the invention, the bit-budget for the j-th picture is allocated by a down-scaling transformation as follows:

$$target_pict_size(j) = input_pict_size(j) * (target_bit_rate / input_bit_rate).$$

In an alternative embodiment, bit-allocation for the j-th picture accumulates the bit-budgets of all macroblocks (MBs):

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$$target_pict_size(j) = \sum_{i=0}^{munber_of_MBs-1} round(input_mb_size(i) * target_bit_rate / input_bit_rate + 0.5)$$

where the *round*(*) function performs a rounding-toward zero and *input_mb_size(i)* denotes the bit-count of the i-th input MB. It should be understood that *input_mb_size(I)*target_bit_rate/input_bit_rate* is the target MB size. The bit-budget *target_pict_size(j)* for the j-th picture is checked against the *vbv_buffer_fullness(j)* to prevent the VBV buffer under- and over-flows. The condition on the VBV buffer under-flow provides an upper limit on the bit-budget. The reason is that, at the time of decoding, the current picture should be small enough so that it is contained entirely inside the decoder buffer.

It is known for transcoder that *target_pict_size(j)* needs to satisfy *target_pict_size(j) < input_pict_size(j).*

If the current picture size is too small, then Eq. (1a) might exceed the *max_vbv_buffer_fullness(j+1)* and then cause decoder buffer overflow. Thus a lower limit is placed on the current picture size. This may be achieved, for example, by limiting the bit budget, and if the actual bits used is still smaller than the minimum picture size, then the end of the picture may be stuffed with zero's. The lower limit is derived from Eqs.(1a) and (1e) as follows.

target_pict_size(j) > vbv_buffer_size + T_{max} - vbv_buffer_fullness(j-1) + T_{min} .

where $T_{min}=(t_{e,j} - t_{e,j-1})\ R_{min}$ and R_{min} is the maximum channel bit-rate between $t_{e,j} - t_{e,j-1}$. Note that $R_{min} = R_{max}$ for the CBR channel.

The inequality condition of (1e) is verified for each slice or frame to prevent the encoder buffer under-flow.

Down-scaling bit-allocation takes advantage of information provided by the input bitstream for CBR applications. For VBR applications, the down-scaling process requires an instantaneous bit-rate for each picture or every few pictures. This bit-rate, associated with *max_vbv_buffer_fullness*, can be provided from StatMux.

It is shown in the next section that the target picture size or the target MB size will effect the virtual buffer fullness and, as a consequence, it will generate the quantization scale for the corresponding MB.

In general, the quantization scale (denoted by *mquant*) for the transcoded bitstream can also generated through a scaling process. Some commonly-used bit-allocation models are:

ISDOCID <WO 0046997A1 IA>

(1) $T = \frac{k_0}{Q}$ in MPEG-2 Test Model 5(TM5) [3].

(2) $T = \frac{k_0}{Q} + \frac{k_1}{Q^2}$ in MPEG-4 verification model [4].

Where T is the bit-budget for a picture or a slice or a MB, and k_0, k_1 are constants that are generated by a pre-estimation[4], and Q denotes the quantization scale corresponding to a picture or a slice or a MB, respectively. Since $T_{target} / T_{input} = target_bit_rate / input_bit_rate$, the quantization scale for the transcoded MBs thus can be estimated by:

For the model $T = \frac{k_0}{Q}$, $Q_{target} = Q_{input} \cdot \frac{input_bit_rate}{target_bit_rate}$,

For the model $T = \frac{k_0}{Q} + \frac{k_1}{Q^2}$, the quantization scale Q can be computed by solving a quadratic equation : $Q_{target} = \frac{k_0 + \sqrt{k_0^2 + 4 \cdot B \cdot k_1}}{2 \cdot B}$ where

$$B = \frac{target_bit_rate}{input_bit_rate} \cdot \left(\frac{k_0}{Q_{input}} + \frac{k_1}{Q_{input}^2} \right).$$

Where Q_{input} can be the average quantization level for this picture or slice at the input, or the quantization level of the MB at the input. The same process can also be applied to other bit-allocation models.

Adjustment to the quantization scale may be accomplished according to the embodiment illustrated below. Let Q_v denote the quantization scale determined by the virtual buffers fullness and Q_{target} be the up-scaled quantization level given above.

Assume that Q_{target} is the up-scaled quantization level for a given MB. Then, the quantization scale Q_T for the MB is determined by

If($\sum_{0}^{current}$ coded_mb_size> $\sum_{0}^{current}$ target_mb_size)

$$Q_T = \max\left(Q_{target}, Q_v\right);$$

else

$$Q_T = \min\left(Q_{target}, Q_v\right).$$

ISDOCID <WO 0046997A1 IA>

In an alternative embodiment, the quantization scale may be adjusted as follows. Assume that Q_{target} is the up-scaled quantization level for a given picture or slice at the input and Q_{input} is the average quantization level for this picture or slice at the input, respectively. Then,

$$Q_{targetMB} = Q_{inputMB} + (Q_{input} - Q_{target}) .$$

The quantization level Q_T for the MB is determined by

$$\text{If}\left(\sum_{0}^{current} \text{coded_mb_size} > \sum_{0}^{current} \text{target_mb_size}\right)$$

$$Q_T = \max\left(Q_{targetMB}, Q_v\right),$$

else

$$Q_T = \min\left(Q_{targetMB}, Q_v\right).$$

The down-scaling process for bit-allocation is applied to the macroblock levels for their bit-budget estimation, and is described below with rate-buffer management and rate-control. According to an embodiment of the present invention, a rate management process includes five steps. In this embodiment, the down-scaling process for bit-allocation is only applied to the macroblock levels, which simplifies the bit- parser and counting process. For CBR applications, such a down-scaling process ensures that the VBV buffer never overflows for a "legal" input bitstream.

1. Initial conditions in Sequence Level

The *vbv buffer* is initially filled the *vbv_buffer_fullness* amount of bits. For CBR applications, *vbv_buffer_fullness* =vbv_delay*target_bit_rate/90000. For VBR applications, the initial *vbv_buffer_fullness* is often derived from the decoding time-stamp of the first picture, i.e. *vbv_buffer_fullness = buffer bit level right before decoding of the first picture.* For the elementary stream-only case, it is initially assumed that:

vbv_buffer_fullness = max(min((2**bit_rate*)/ *frame_rate*, *max_vbv_buffer_fullness*/ 5) , K1)

if the initial quantizer is non-linear and:

vbv_buffer_fullness = max(min((4**bit_rate*)/ *frame_rate*, *max_vbv_buffer_fullness*/ 2) , K2)

ISDOCID <WO 0046997A1 IA>

if the initial quantizer is linear , where K1 and K2 are constants. In one embodiment, the values for the constants may be K1=100000 and K2=200000. In an alternative embodiment of the invention, in a similar manner to the MPEG-2 test model 5 (TM5) [3], three virtual buffers are used to measure the buffer fullness.

2. Initial Conditions in Picture Level

The additional parameters required in the picture level are the quantization scale type : *q_scale_type* and the average quantization level *avg_Q_prev_pict* of the previous picture.

Two variables need to be set for the rate-control in the picture level: (1) the initial virtual buffer fullness for the picture; (2) the bit budget for this picture. Also, the bits from picture header (and sequence header and GOP header for the beginning of the sequence or GOP) , *header_bits,* are extracted.

The virtual buffer fullness *d* is set to be the virtual buffer fullness of the current picture type, i.e.

case I_TYPE : $d = d0i$;

case P_TYPE : $d = d0p$;

case B_TYPE : $d = d0b$.

(2) The bit budget for this picture, denoted by *target_pict_size*, is allocated by a very simple transformation as follows:

target_pict_size = input_pict_size(target_bit_rate/input_bit_rate)*

For CBR applications, *target_bit_rate/input_bit_rate* is pre-computed after parsing the sequence header.

3. Update Variables in Picture Level

Two variables are updated in the picture level: the virtual buffer fullness *d.* and the quantization type *q_scale_type* for this picture.

(1) d + = *coded_pict_size* – *target_pict_size* , and

case I_TYPE : $d0i=d$;

case P_TYPE : $d0p=d$;

case B_TYPE : $d0b=d$

(2) The *q_scale_type* for this picture is determined by the following rules :

If this picture is the first picture or an I-picture, keep the *q_scale_type* to be the same as the corresponding input picture;

ISDOCID: <WO___0046997A1_IA>

Otherwise, *q_scale_type* is set as follows :

If (*avg_Q_prev_pict<T1 || avg_Q_prev_pict>T2*) *q_scale_type = 1 ;*

If (*avg_Q_prev_pict > T3 && avg_Q_prev_pict < T4) q_scale_type = 0;*

Where avg_Q_prev_pict is the average mquant of the previous frame and *T1<T3<T4<T2*. The typical values for *T1, T2, T3*, and *T4* are:

T1=15, T2=25, T3=18 and *T4 =22.*

If *q_scale_type* is not set, the input *q_scale_type* is used.

At the end of a picture, the video buffer verifier fullness *vbv_buffer_fullness* is updated. The minimum picture size *min_pict_size* is compared with the actual coded picture size *coded_pict_size* for the frame just coded. If a deficit exists, ones are appended to the end of that frame.

4. Initial Variables in Macroblock Level

An initial quantization step-size (mquant) needs to be computed at the beginning of each picture. Such a quantization step-size is generated by an up-scaling conversion of the quantization step-size (input_mquant) of the corresponding input macroblock :

mquant = input_mquant*(input_bit_rate/target_bit_rate);

5. Updated Variables in Macroblock Level

The macroblock (MB) quantization step-size, mquant, is updated by a use of a virtual buffer discrepancy. The virtual buffer discrepancy is calculated by the following formula :

Virtual buffer discrepancy = d + the cumulated bits up to the current MB of a picture - the cumulated MB-bit-budget up to the current MB of a picture.

The MB-bit-budget for each MB may also be computed by a down-scaling conversion:

mb_bit_budget = input_mb_bitcount*(target_bit_rate/input_bit_rate).

Although the invention has been described with reference to specific exemplary embodiments, it will be appreciated that it is intended to cover all modifications and equivalents within the scope of the appended claims.

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WHAT IS CLAIMED IS:

1. A method of managing a video transmission bit-rate in a transcoder, comprising the steps of:

measuring a fullness of an input buffer of the transcoder;

providing a bit budget for one of plurality of frames in an input bitstream, the bit budget being based on a quantization parameter of said video frames;

measuring an actual bit-rate of said input video stream;

comparing said actual bit-rate with said buffer fullness to predict an input buffer underflow or overflow; and

in response to an input buffer underflow, incrementing said bit budget for a next one of said plurality of video frames, and in response to an input buffer overflow, decrementing said bit budget for next one of said plurality of video frames.

2. A method of controlling a bit-rate of a plurality of pictures in a video transcoder, where the transcoder includes a decoder and an encoder, the method comprising the steps of:

determining a bit budget for a current picture at an input to the decoder;

measuring a buffer fullness of an encoder buffer when the encoder buffer receives a previous picture; and

allocating a number of bits to the current picture based on the buffer fullness, such that the allocated bits of the current picture is within the bit budget.

3. The method according to claim 2, wherein the step of determining a bit budget further comprises the steps of:

determining a size of available encoder buffer capacity after the encoder buffer receives a previous picture; and

measuring a coded picture size of the current picture at the input to the decoder.

4. The method according to claim 2, wherein the step of measuring a buffer fullness further comprises the step of determining the encoder buffer capacity.

5. The method according to claim 2, wherein the step of allocating a number of bits to the current picture further comprises the step of adjusting a quantization of a decoded picture.

ISDOCID: <WO 0046997A1 IA>

6. The method according to claim 2, wherein the step of allocating a number of bits to the current picture further comprises the steps of:

setting a target bit size for the current picture;

measuring an actual bit size for the current picture; and

adjusting a quantization level for the current picture based on a differential between the target bit size and the actual bit size for the current picture,

wherein the target bit size is calculated to be within a range of available encoder buffer bit space.

7. A system for controlling a bit-rate of a plurality of pictures in a video transcoder, where the transcoder includes a decoder and an encoder, comprising:

means for determining a bit budget for a current picture at an input to the decoder;

means for measuring a buffer fullness of an encoder buffer when the encoder buffer receives a previous picture; and

means for allocating a number of bits to the current picture based on the buffer fullness, such that the allocated bits of the current picture is within the bit budget.

8. The system according to claim 7, further comprising:

a video buffering verifier having configured to monitor the encoder buffer and measure the buffer fullness; and

a controller, coupled with the video buffering verifier, and configured to receive bit-rate information from a transmission channel input to the decoder, wherein the bit-rate information is compared with the buffer fullness to allocate the number of bits to the current picture.

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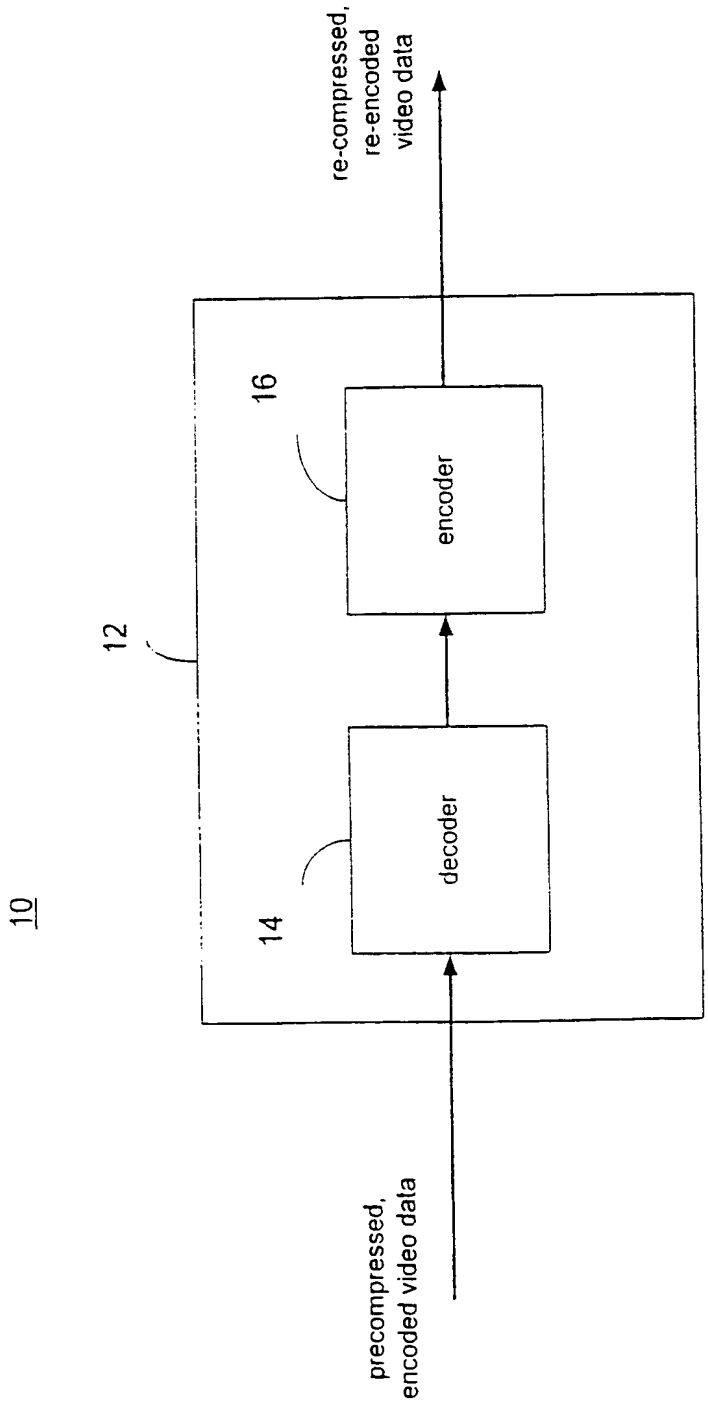

Fig. 1 (prior art)

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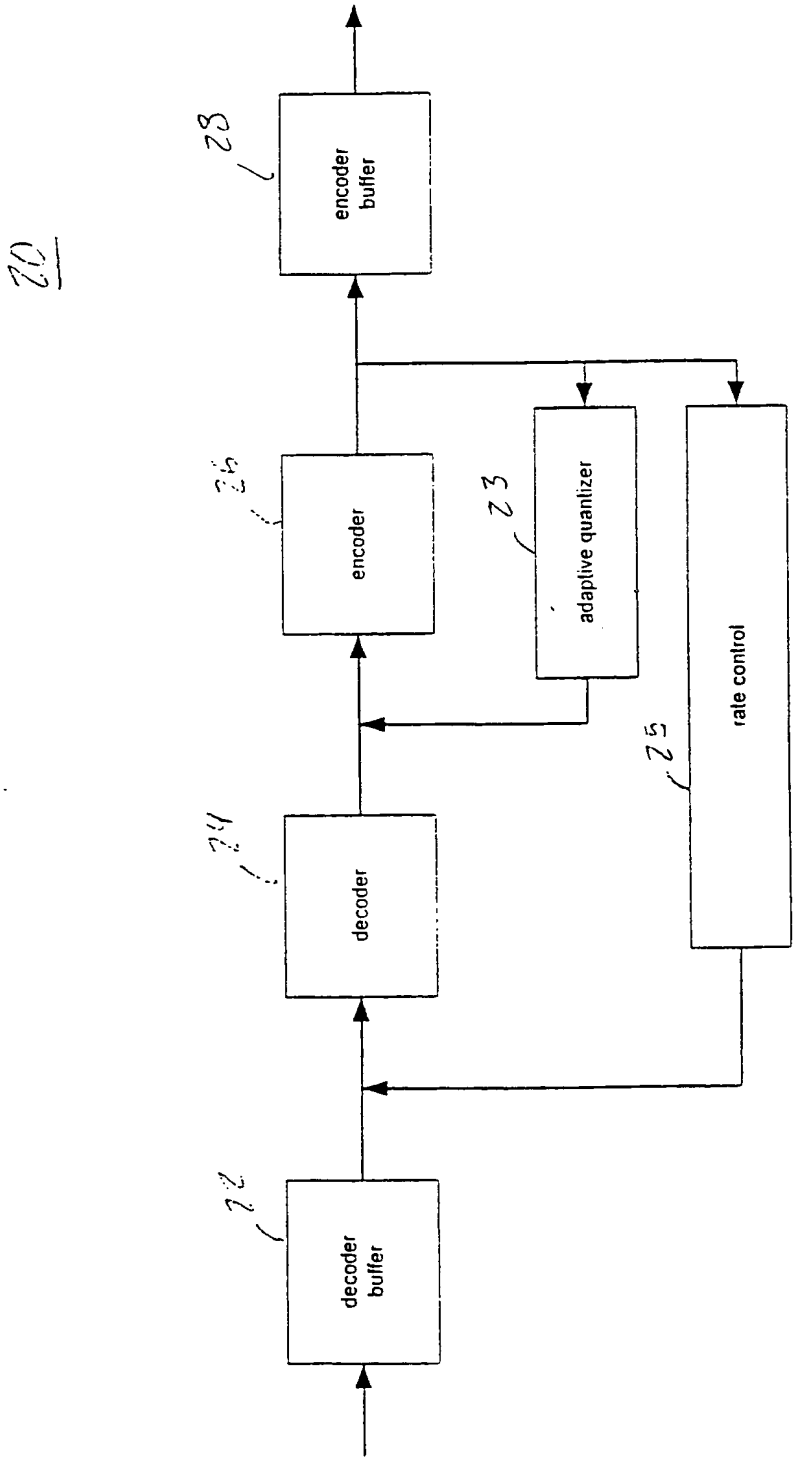

Fig. 2 (prior art)

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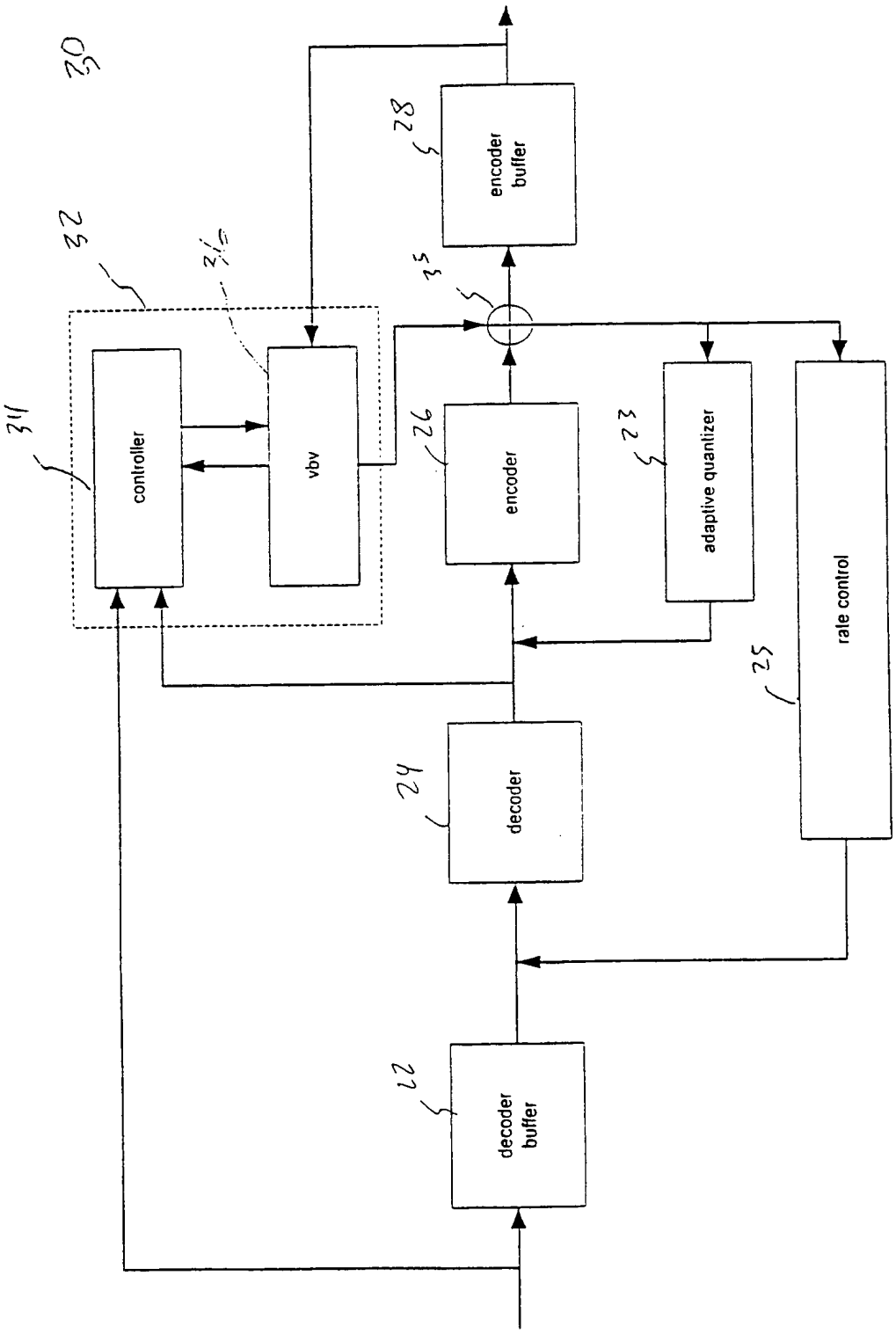

Fig. 3

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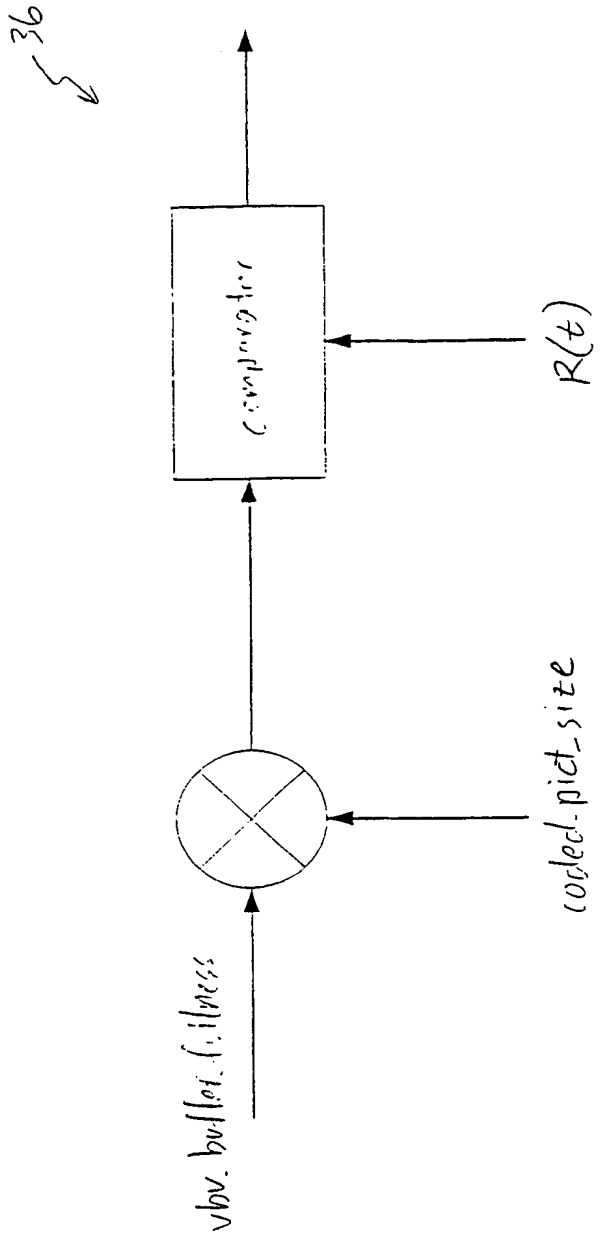

Fig 4

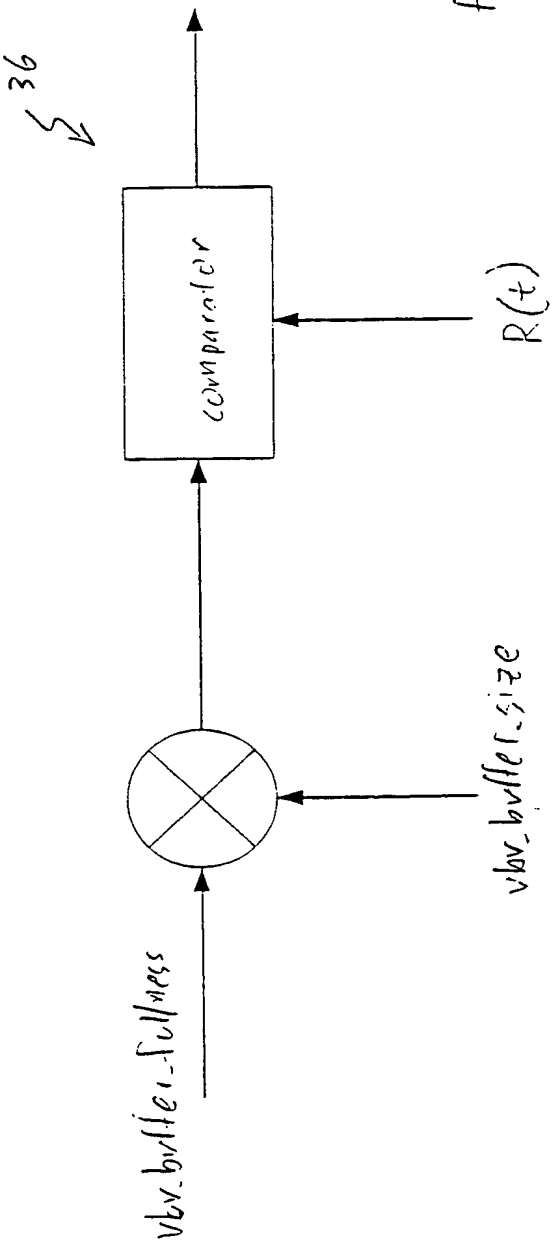

Fig 5

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INTERNATIONAL SEARCH REPORT

Int. ional Application No
PCT/US 00/02967

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04N7/26 H04N7/50

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 711 077 A (AT & T CORP) 8 May 1996 (1996-05-08)	2-5,7
A	page 4, column 5, line 43 -column 6, line 27 page 7, column 12, line 16 -page 8, column 14, line 32	7,8
A	US 5 805 224 A (VAN OTTERLOO PETRUS J ET AL) 8 September 1998 (1998-09-08) page 5, line 35 -page 6, line 21	2-7

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 June 2000	07/07/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx 31 651 epo nl, Fax: (+31-70) 340-3016	Marie-Julie, J-M

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INTERNATIONAL SEARCH REPORT

Int[illegible]ional Application No
PCT/US 00/02967

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication.where appropriate. of the relevant passages	Relevant to claim No.
A	SUN H ET AL: "ARCHITECTURES FOR MPEG COMPRESSED BITSTREAM SCALING" IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY,US,IEEE INC. NEW YORK, vol. 6, no. 2, 1 April 1996 (1996-04-01), pages 191-199, XP000583538 ISSN: 1051-8215 paragraphs '000A!,'000B!	1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

ISDOCID <WO 0046997A1 IA>

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int tional Application No
PCT/US 00/02967

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0711077 A	08-05-1996	US 5687095 A	11-11-1997
		CA 2159846 A	02-05-1996
		JP 8242451 A	17-09-1996
US 5805224 A	08-09-1998	AU 703049 B	11-03-1999
		AU 4398496 A	04-09-1996
		DE 69607696 D	18-05-2000
		EP 0755610 A	29-01-1997
		WO 9625823 A	22-08-1996
		JP 9512410 T	09-12-1997

VSDOCID: <WO 0046997A1 IA>

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Event Building for LHC

XP-002240087

5.1 Little's Law

Although an event building system can in principal be described as a network of queues the details of the interconnecting network and the interdependence of the queues are difficult to express in mathematical probability functions. The approach of queueing theory is therefore not followed here and only one result from queueing theory will be reported: Little's law. This states [Kle75]:

The average number of customers in a queueing system N is equal to the average arrival rate of customers to that system &lambda, *times the average time spent in that system T:*

$$N = \lambda \cdot T$$

This law which can be understood intuitively is a formal result of queueing theory and does not depend on any specific assumptions regarding the arrival time distribution, the service time distribution, the number of servers or the queueing discipline. For an event building system it relates the number of full events N_{Fvt} to the latency L:

(EQ 5.1) $\langle N_{Fvt} \rangle = \langle f \rangle \langle L \rangle$

where f is the input frequency (see section 3.1.3). Little's law can also be applied for the event fragments:

(EQ 5.2) $\langle B \rangle = \langle f \rangle \cdot \langle L_{Frg} \rangle$

Using the relation of latency and fragment latency (equation 3.3) and Little's law in the two forms one can derive a relation between buffer occupancy and latency:

(EQ 5.3) $\langle B \rangle \leq \langle f \rangle \cdot \langle L \rangle$

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